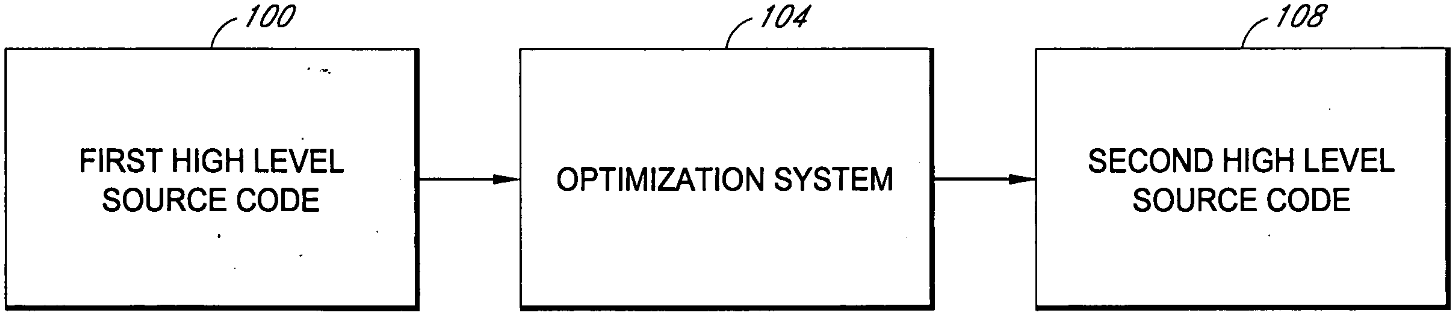
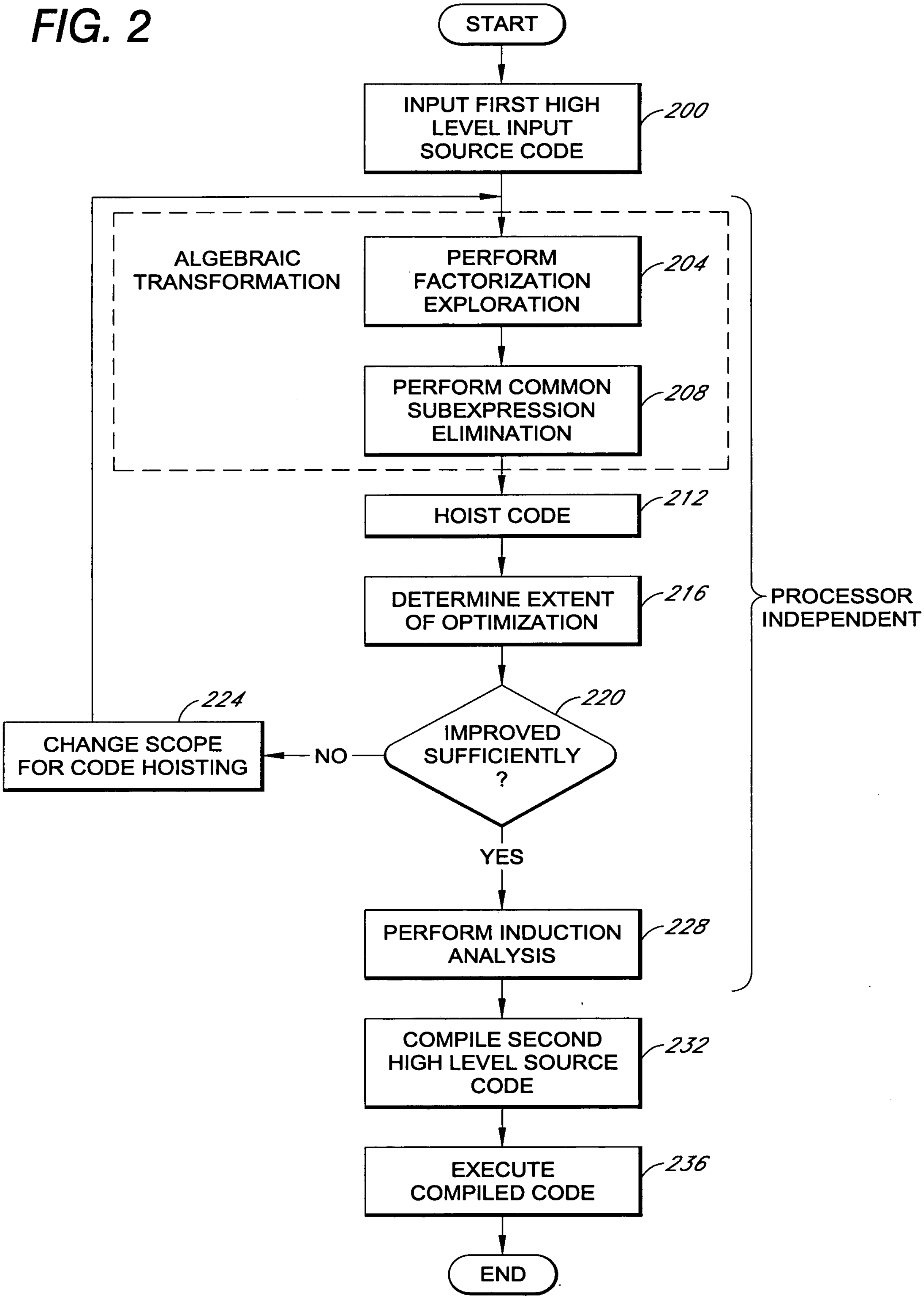

100
FIRST HIGH LEVEL SOURCE CODE
104
OPTIMIZATION SYSTEM
108
SECOND HIGH LEVEL SOURCE CODE

FIG. 1

FIG. 2


START
INPUT FIRST HIGH LEVEL INPUT SOURCE CODE
200
ALGEBRAIC TRANSFORMATION
PERFORM FACTORIZATION EXPLORATION
204
PERFORM COMMON SUBEXPRESSION ELIMINATION
208
HOIST CODE
212
DETERMINE EXTENT OF OPTIMIZATION
216
IMPROVED SUFFICIENTLY ?
220
NO
CHANGE SCOPE FOR CODE HOISTING
224
YES
PERFORM INDUCTION ANALYSIS
228
PROCESSOR INDEPENDENT
COMPILE SECOND HIGH LEVEL SOURCE CODE
232
EXECUTE COMPILED CODE
236
END

```
for (y=0 ; y<M+3 ; ++y) {
  for (x=0 ; x<N+5 ; ++x) {
    . . .
    if ( (x-3) >=1 && (x-5) <=N-2 && (y-2) >=1 && (y-3) <=M-2) {
      if ( (x-5) >=1 && (y-3) >=1 {
        if (out_compute == 255) {
          if (comp_edge_pixels [ ( (x-4) %3) *3+ (y-2) %3 ] <comp_edge_middle) out_compute=0 ;
                                 . . .
          if (comp_edge_pixels [ ( (x-4) %3) *3+ (y-4) %3] <comp_edge_middle) out_compute=0 ;
                                 . . .
          if (comp_edge_pixels [ ( (x-5) %3) *3+ (y-4) %3] <comp_edge_middle) out_compute=0 ;
                                 . . .
        }
      }
      if ( (x-3) <=N-2 && (y-2) <= (M-2) ) {
        maxdiff_compute =
          max13 (abs (gauss_xy_pixels [ ( (x-2) %3) *3+ (y-1) %3 ]
                   - gauss_xy_middle) , maxdiff_compute) ;
                                 . . .
        maxdiff_compute =
          max13 (abs (gauss_xy_pixels [ ( (x-2) %3) *3+ (y-3) %3 ]
                   - gauss_xy_middle) , maxdiff_compute) ;
                                 . . .
        maxdiff_compute =
          max13 (abs (gauss_xy_pixels [ ( (x-3) %3) *3+ (y-3) %3 ]
                   - gauss_xy_middle) , maxdiff_compute) ;
                                 . . .
      }
    }
    . . .
  }
}
```

FIG. 3

FIG. 4

```
for (y=0 ; y<M+3 ; ++y) {
   for (x=0 ; x<N+5 ; ++x) {
        . . .
      if (x>=4 &&  x<=N+3 &&  y>=3 && y<=M+1) {
         if ( (x-5) >=1 && (y-3) >=1) {
            if (out_compute == 255) {
               csexmin4mod3x3 = ( (x-4) %3) *3 ;
               cseymin4mod3 = (y-4) %3 ;
                  if (comp_edge_pixels [ csexmin4mod3x3 + (y-2) %3 ] <comp_edge_middle) out_ compute=0 ;
                                       . . .
                  if (comp_edge_pixels [ csexmin4mod3x3 +cseymin4mod3 ] <comp_edge_middle) out_ compute=0 ;
                                       . . .
                  if (comp_edge_pixels [ ( (x-5) %3 ) *3 + (cseymin4mod3) <comp_edge_middle) out_ compute=0 ;
                                       . . .
               }
            }
            if ( (x-3) <=N-2 && (y-2) <= (M-2) ) {
               csexmin2mod3x3 = ( (x-2) %3) *3 ;
               cseymod3 = y%3 ; /* = (y-3) %3 */
               maxdiff_compute =
                  max13 (abs (gauss_xy_pixels [ csexmin2mod3x3 + ( y-1) %3 ]
                                 - gauss_xy_middle) , maxdiff_compute) ;
                                       . . .
               maxdiff_compute =
                  max13 (abs (gauss_xy_pixels [ csexmin2mod3x3 + cseymod3 ]
                                 - gauss_xy_middle) , maxdiff_compute) ;
                                       . . .
               maxdiff_compute =
                  max13 (abs (gauss_xy_pixels [ (x%3) *3 + cseymod3 ]
                                 - gauss_xy_middle) , maxdiff_compute) ;
                                       . . .
            }
         }
         . . .
      }
   }
```

distributivity : (x + 4) %3 = (x%3 + 4%3) %3
constant folding : = (x%3 + 1) %3
constant unfolding : = (x%3 + 1%3) %3
invert distributivity : = (x + 1_ %3

(a)

modulo expansion: (x+2) %3 = 3 - x%3 - (x=1) %3

(b)

FIG. 5

```
for (y=0 ; y<M+3 ; ++y) {
  cseymod3 = y%3 ;
  cseymin1mod3 = (y-1) %3 ;
  cseymin2mod3 = (y-2) %3 ;
  cseymin4mod3 = (y-4) %3 ;
  for (x=0 ; x<N+5 ; ++x) {
        . . .
    if (x>=4 && x<=N+3 && y>=3 && y<=M+1) {
      if ( (x-5) >=1 && (y-3) >=1) {
        if (out_compute == 255) {
        cseymin4mod3x3 = ( (x-4) %3) *3 ;
          if (comp_edge_pixels [ csexmin4mod3x3 + cseymin2mod3 ] <comp_edge_middle) out_ compute=0 ;
                     . . .
          if (comp_edge_pixels [ csexmin4mod3x3 +cseymin4mod3 ] <comp_edge_middle) out_ compute=0 ;
                     . . .
          if (comp_edge_pixels [ ( (x-5) %3 ) *3 + cseymin4mod3 ] <comp_edge_middle) out_ compute=0 ;
                     . . .
        }
      }
      if ( (x-3) <=N-2 && (y-2) <= (M-2) ) {
        csexmin2mod3x3 = ( (x-2) %3) *3 ;
        maxdiff_compute =
          max13 (abs (gauss_xy_pixels [ csexmin2mod3x3 + cseymin1mod3 ]
                     - gauss_xy_middle) , maxdiff_compute) ;
                       . . .
        maxdiff_compute =
          max13 (abs (gauss_xy_pixels [ csexmin2mod3x3 + cseymod3 ]
                     - gauss_xy_middle) , maxdiff_compute) ;
                       . . .
        maxdiff_compute =
          max13 (abs (gaus_xy_pixels [ (x%3) *3 + cseymod3 ]
                     - gauss_xy_middle) , maxdiff_compute) ;
                       . . .
      }
    }
    . . .
  }
}
```

FIG. 6

```
cseymod3 = -1 ;
for (y=0 ; y<M+3 ; ++y) {
   cseymin1mod3 = cseymod3 ;
   cseymod3 = y%3 ;
   cseymin2mod3 = 3-cseymod3-cseymin1mod3 ;
   for (x=0 ; x<N+5 ; ++x) {
         . . .
      if (x>=4 && x<=N+3 && y>=3 && y<=M+1) {
         if ( (x-5) >=1 && (y-3) >=1) {
            if (out_compute == 255) {
            csexmin4mod3x3 = ( (x-4) %3 *3 ;
               if (comp_edge_pixels [ csexmin4mod3x3 + cseymin2mod3 ] <comp_edge_middle) out_ compute=0 ;
                                             . . .
               if (comp_edge_pixels [ csexmin4mod3x3 +cseymin1mod3 ] <comp_edge_middle) out_ compute=0 ;
                                             . . .
               if (comp_edge_pixels [ ( (x-5) %3 ) *3 + (cseymin1mod3) <comp_edge_middle) out_ compute=0 ;
                                             . . .
            }
         }
         if ( (x-3) <=N-2 && (y-2) <= (M-2) ) {
            csexmin2mod3x3 = ( (x-2) %3) *3 ;
            maxdiff_compute =
               max13 (abs (gauss_xy_pixels [ csexmin2mod3x3 + cseymin1mod3 ]
                              - gauss_xy_middle) , maxdiff_compute) ;
                                 . . .
            maxdiff_compute =
               max13 (abs (gauss_xy_pixels [ csexmin2mod3x3 + cseymod3 ]
                              - gauss_xy_middle) , maxdiff_compute) ;
                                 . . .
            maxdiff_compute =
               max13 (abs (gaus_xy_pixels [ (x%3) *3 + cseymod3 ]
                              - gauss_xy_middle) , maxdiff_compute) ;
                                 . . .
         }
      }
      . . .
   }
}
```

FIG. 7

```
cseymod3 = -1 ;
for (y=0 ; y<M+3 ; ++y) {
   cseymin1mod3 = cseymod3 ;
   cseymod3 = y%3 ;
   cseymin2mod3 = 3-cseymod3-cseymin1mod3 ;
   for (x=0 ; x<N+5 ; ++x) {
      . . .
      if (x>=4 && x<=N+3 && y>=3 && y<=M+1) {
         csexmod3x3 = (x%3) *3 ;
         csexmin2mod3x3 = ( (x-2) %3) *3 ;
         cseymin4mod3x3 = ( (x-4) %3) *3 ;
         csexmin5mod3x3 = ( (x-5) %3) *3 ;
         if ( (x-5) >=1 && (y-3) >=1) {
            if (out_compute == 255) {
               if (comp_edge_pixels [ csexmin4mod3x3 + cseymin2mod3 ] <comp_edge_middle) out_ compute=0 ;
                         . . .
               if (comp_edge_pixels [ csexmin4mod3x3 +cseymin1mod3 ] <comp_edge_middle) out_ compute=0 ;
                         . . .
               if (comp_edge_pixels [ csexmin5mod3x3 +cseymin1mod3 ] <comp_edge_middle) out_ compute=0 ;
                         . . .
            }
         }
         if ( (x-3) <=N-2 && (y-2) <= (M-2) ) {
            maxdiff_compute =
               max13 (abs (gauss_xy_pixels [ csexmin2mod3x3 + cseymin1mod3 ]
                          - gauss_xy_middle) , maxdiff_compute) ;
                            . . .
            maxdiff_compute =
               max13 (abs (gauss_xy_pixels [ csexmin2mod3x3 + cseymod3 ]
                          - gauss_xy_middle) , maxdiff_compute) ;
                            . . .
            maxdiff_compute =
               max13 (abs (gaus_xy_pixels [ csexmod3x3 + cseymod3 ]
                          - gauss_xy_middle) , maxdiff_compute) ;
                            . . .
         }
      }
      . . .
   }
}
```

FIG. 8

FIG. 9

```
cseymod3 = -1 ;
for (y=0 ; y<M+3 ; ++y) {
   cseymin1mod3 = cseymod3 ;
   cseymod3 = y%3 ;
   cseymin2mod3 = 3-cseymod3-cseymin1mod3 ;
   for (x=0 ; x<N+5 ; ++x) {
         csexmod3x3 = (x%3) *3 ;
         csexmin2mod3x3 = ( (x-2) %3) *3 ;
         cseymin4mod3x3 = ( (x-4) %3) *3 ;
         csexmin5mod3x3 = ( (x-5) %3) *3 ;
           . . .
      if (x>=4 && x<=N+3 && y>=3 && y<=M+1) {
         if ( (x-5) >=1 && (y-3) >=1) {
            if (out_compute == 255) {
               if (comp_edge_pixels [ csexmin4mod3x3 + cseymin2mod3 ] <comp_edge_middle) out_ compute=0 ;
                                . . .
               if (comp_edge_pixels [ csexmin4mod3x3 +cseymin1mod3 ] <comp_edge_middle) out_ compute=0 ;
                                . . .
               if (comp_edge_pixels [ csexmin5mod3x3 +cseymin1mod3 ] <comp_edge_middle) out_ compute=0 ;
                                . . .
            }
         }
         if ( (x-3) <=N-2 && (y-2) <= (M-2) ) {
            maxdiff_compute =
               max13 (abs (gauss_xy_pixels [ csexmin2mod3x3 + cseymin1mod3 ]
                               - gauss_xy_middle) , maxdiff_compute) ;
                                . . .
            maxdiff_compute =
               max13 (abs (gauss_xy_pixels [ csexmin2mod3x3 + cseymod3 ]
                               - gauss_xy_middle) , maxdiff_compute) ;
                                . . .
            maxdiff_compute =
               max13 (abs (gaus_xy_pixels [ csexmod3x3 + cseymod3 ]
                               - gauss_xy_middle) , maxdiff_compute) ;
                                . . .
         }
      }
      . . .
   }
}
```

```
cseymod3 = -1 ;
for (y=0 ; y<M+3 ; ++y) {
   cseymin1mod3 = cseymod3 ;
   cseymod3 = y%3 ;
   cseymin2mod3 = 3-cseymod3-cseymin1mod3 ;
   csexmod3x3 = -3 ;
   for (x=0 ; x<N+5 ; ++x) {
         csexmin1mod3x3 = csexmod3x3 ;
         csexmod3x3 = (x%3) *3 ;
         csexmin2mod3x3 = 9-csexmod3x3-csexmin1mod3x3 ;
           . . .
      if (x>=4 && x<=N+3 && y>=3 && y<=M+1) {
         if ( (x-5) >=1 && (y-3) >=1) {
            if (out_compute == 255) {
               if (comp_edge_pixels [ csexmin1mod3x3 + cseymin2mod3 ] <comp_edge_middle) out_ compute=0 ;
                                    . . .
               if (comp_edge_pixels [ csexmin1mod3x3 +cseymin1mod3 ] <comp_edge_middle) out_ compute=0 ;
                                    . . .
               if (comp_edge_pixels [ csexmin2mod3x3 +cseymin1mod3 ] <comp_edge_middle) out_ compute=0 ;
                                    . . .
            }
         }
         if ( (x-3) <=N-2 && (y-2) <= (M-2) ) {
            maxdiff_compute =
               max13 (abs (gauss_xy_pixels [ csexmin2mod3x3 + cseymin1mod3 ]
                               - gauss_xy_middle) , maxdiff_compute) ;
                                    . . .
            maxdiff_compute =
               max13 (abs (gauss_xy_pixels [ csexmin2mod3x3 + cseymod3 ]
                               - gauss_xy_middle) , maxdiff_compute) ;
                                    . . .
            maxdiff_compute =
               max13 (abs (gaus_xy_pixels [ csexmod3x3 + cseymod3 ]
                               - gauss_xy_middle) , maxdiff_compute) ;
                                    . . .
         }
      }
      . . .
   }
}
```

FIG. 10

FIG. 11

```
cseymod3 = -1 ;
for (y=0 ; y<M+3 ; ++y) {
   cseymin1mod3 = cseymod3 ;
   cseymod3 = y%3 ;
   cseymin2mod3 = 3-cseymod3 - cseymin1mod3 ;
   csexmod3x3 = -3 ;
   cseymin1mod2 = (y-1) %2 ;
   cseymod2 = 1 - cseymin1mod2 ;
   for (x=0 ; x<N+5 ; ++x) {
         csexmin1mod3x3 = csexmod3x3 ;
         csexmod3x3 = (x%3) *3 ;
         csexmin2mod3x3 = 9-csexmod3x3 - csexmin1mod3x3 ;
         csexmin1x2 = (x-1) *2 ;
         csexmin3x2 = csexmin1x2-4 ;
                        . . .
      if (x>=3 && x<N+3 && y>=2 && y<=M+2)
         tmparray [ (csexmin3x2 + cseymod2) %160
                                  + (csexmin3x2 + cseymod2) / 160*256 + 96 ]
               = comp_edge_pixels [ csexmod3x3
                                           + cseymin2mod3 ] = maxdiff_compute ;
                        . . .
      if (x>=1 && x<N+1 && y>=1 && y<=M)
         tmparray [ (csexmin1x2 + cseymin1mod2) %64
                                  + (csexmin1x2 + cseymin1mod2) / 64*256 ]
               = gauss_xy_pixels [ csexmin1mod3x3
                                           + cseymin1mod3 ] = gauss_xy_compute ;
            . . .
         }
      }

   }
}
```

```
cseymod3  =  -1 ;
for  (y=0 ;  y<M+3 ;  ++y)  {
   cseymin1mod3  =  cseymod3 ;
   cseymod3  ++ ;
   if (cseymod3  >=  3) { cseymod3  -=  3 ; }
   cseymin2mod3  =  3-cseymod3 - cseymin1mod3 ;
   cseymin1mod2  =  (y-1) &1 ;
   cseymod2 = 1 - cseymin1mod2 ;
   csexmod3x3 =  -3 ;
   csexx2mod160_1_2 = cseymod2 - 8 ;
   csexx2div160_1_2 = 0 ;
   for  (x=0 ;  x<N+5 ;  ++x)  {
         csexmin1mod3x3  =  csexmod3x3 ;
         csexmod3  ++ ;
         if (csexmod3  >=  3) { csexmod3  -=  3 ; }
         csexmod3x3 = csexmod3 * 3 ;
         csexmin2mod3x3  =  9 - csexmod3x3 - csexmin1mod3x3 ;
         csexx2mod160_1_2+ = 2 ;
         csexmin1x2  =  (x-1) *2 ;
         csexmin3x2  =  csexmin1x2 - 4 ;
         if (csexx2mod160_1_2>=160)  { csexx2mod160_1_2 - = 160 ; csexx2div160_1_2 ++ ; }
                     . . .
      if  (x>= 3  &&  x<N+3  &&  y>=2  &&  y<M+2)
         tmparray [ csexx2mod160_1_2  +  csexx2div160_1_2 * 256  +  96 ]
               =  comp_edge_pixels [ csexmod3x3
                                                   +  cseymin2mod3 ]  =  maxdiff_compute ;

      if  (x>= 1  &&  x<N+1  &&  y>=1  &&  y<=M)
         tmparray [ ( (csexmin1x2 +  cseymin1mod2) &63)
                                   +  ( (csexmin1x2 +  cseymin1mod2) >>6) * 256 ]
               =  gauss_xy_pixels [ csexmin1mod3x3
                                                   +  cseymin1mod3 ]  =  gauss_xy_compute ;
            . . .
         }
      }

   }
}
```

FIG. 12

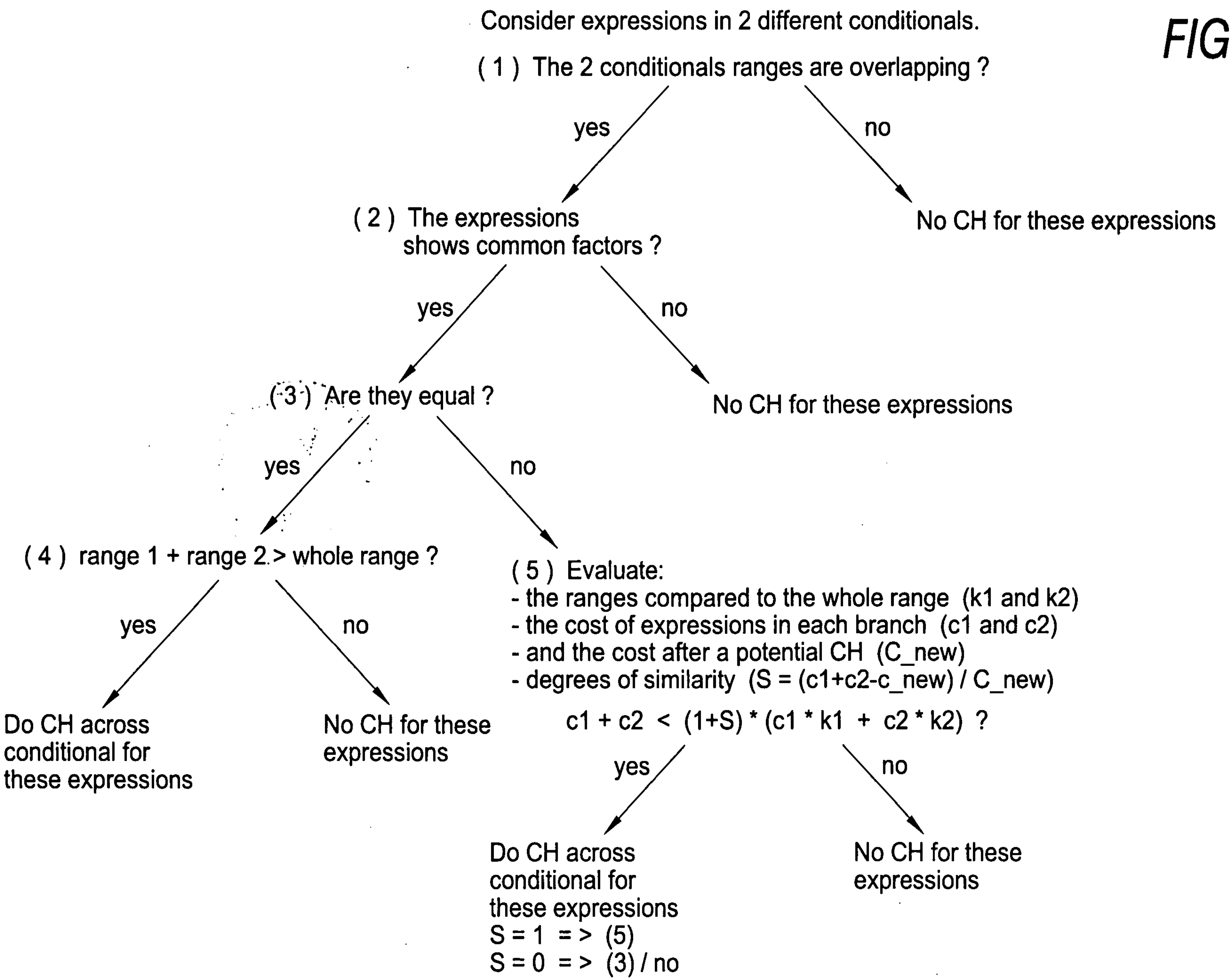

Consider expressions in 2 different conditionals.
(1) The 2 conditionals ranges are overlapping ?
yes
no
No CH for these expressions
(2) The expressions shows common factors ?
yes
no
No CH for these expressions
(3) Are they equal ?
yes
no
(4) range 1 + range 2 > whole range ?
yes
no
Do CH across conditional for these expressions
No CH for these expressions
(5) Evaluate:
- the ranges compared to the whole range (k1 and k2)
- the cost of expressions in each branch (c1 and c2)
- and the cost after a potential CH (C_new)
- degrees of similarity (S = (c1+c2-c_new) / C_new)
c1 + c2 < (1+S) * (c1 * k1 + c2 * k2) ?
yes
no
Do CH across conditional for these expressions
S = 1 = > (5)
S = 0 = > (3) / no
No CH for these expressions

FIG. 13